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PROGRESS REPORT
Title: Research on the Natural Variability of Climate and the Impact of Anthropogenic Forcing on Climate
Award Number: NNG04GF12A

The paper, "Latitude-dependent vertical mixing and the tropical thermocline in a global OGCM", was revised and published in Geophysical Research Letters (Canuto et al. 2004 Vol.31,23,L16305). It treats the new GISS mixing scheme which includes the latitudinal dependence of the interior ocean turbulence field reported by Gregg, Sanford & Winkel (2003 Nature Vol.422). When implemented in the 3X3 degree NCAR CSM1 OGCM [NCOM1] the new mixing scheme produces an improved, sharper equatorial thermoclines in both the Atlantic and the Pacific while simultaneously maintaining the realistic meridional overturning and northward heat transports found already with the previous GISS scheme. Also the paper "Diagnostics of the oceanic thermohaline circulation in a coupled climate model" describing earlier work on the grany was published (Bleck, R., and S. Sun, 2004: Global and Planetary Change, 40, 233--248.

During and after a visit to MIT, Dr. Howard successfully implemented the new GISS mixing scheme in the MIT OGCM and carried out a hundred year simulation run. Cases of isolated intermittent but recurring high diffusivity points below the thermocline that had been found with the NCOM1 did not appear in the MIT OGCM run, perhaps due to the OGCM's different numerical schemes. The code has been given to J. Scott of MIT who will test it also in coupled ocean-atmosphere simulations.

In the summer of 2004 in collaboration with G. Catalano of SUNY Binghamton, Dr. Howard continued work on adding to the GISS scheme a parameterization for the effects of rotation on ocean deep convection. Debugging proceeded on the subroutines to be used to calculate the dimensionless turbulence functions of stratification and the Earth's rotation vector that will be needed to calculate mixing with the new model incorporating rotation. Tests were performed in which output from the present GISS model referenced above was supplied as input data to the new subroutines. The tests revealed programming issues that need to be resolved.

With the assistance of C. Muller, an NYU graduate student, Dr. Howard is extending the GISS scheme in another direction. The interaction of tides with the ocean bottom leads to mixing in the lower part of the ocean in some cases orders of magnitude greater than that at intermediate depths, but which is highly spatially variable depending on topography. Maps of calculated tidal dissipation have recently become available, e.g. Laurent et al. (2002 GRL Vol.29,23,2106); and Simmons et al. (2004 Ocean Modeling Vol.6,p245) and Saenko & Merryfield (Journal of Physical Oceanography in press). A mixing scheme based on these distributions and assuming a constant mixing efficiency has been constructed. The GISS turbulence model currently predicts a variation of the mixing efficiency depending on the salinity and temperature gradients. We accordingly began a project to better represent the tidally induced mixing by including it within our turbulence framework.

Drs. Howard and Canuto participated in the Oct.2004 IAPSO/SCOR Ocean Mixing Conference in Victoria, British Columbia and there held discussions with W. Merryfield. We implemented tidally induced mixing in the GISS scheme using a map of wave dissipation provided by S. Jayne and performed simulations with the NCOM1 using a range of values for the fraction q of tidal energy released that is available for local mixing, as this is a quantity which is not yet well constrained. Preliminary results were encouraging and were subsequently presented at the Jan.2005 Layered Ocean Model Workshop in Miami, Florida. Tidally induced mixing improved the agreement of global temperature and salinity profiles with Levitus. The ocean became cooler and fresher near the surface and warmer and saltier near the bottom, the strens not yet been included in our or other group's simulations. S. Jayne has kindly provided us with new tidal simulation data from which we can calculate the drag as well as an improved map of tidal wave dissipation. In order to properly implement the tidal drag it is necessary to add a bottom boundary layer to the GISS mixing scheme and coding to do this as well as parameterize shear due to the drag not resolved in the OGCM has been underway and is nearing completion.

For the first half of 2004, Dr. Sun focused mainly on development of the coupled GISS-HYCOM model. Both the AGCM and OGCM modules have been modified in great detail in the past few years, and the resulting new version of the coupled model has shown improvement in many aspects. From June to August, Dr. Sun and Dr. Howard worked on implementing the GISS mixing scheme in the HYCOM model. Subsequently Dr. Howard in collaboration with L. Montenegro and A. Romanou continued to work on this implementation.

Dr. Sun carried out all the runs with the GISS-HYCOM model requested by the IPCC. She carried out 4 different runs and the data were submitted before the IPCC deadline. The runs include a 500 year control run, a 250 year doubled CO2 run, ensemble runs for the 20th century and andd the A1B scenario for the 21th century.